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The Effect of Sleep Quality and High Intensity Physical Activity on Inflammation and Cardiovascular Disease Risk Factors in College Students

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Abstract

Background: Obesity, diabetes, and depression are chronic conditions prevalent among Americans and the common denominator in all of these conditions is inflammation. While it is suggested that adequate exercise and optimal sleep quality help maintain normal inflammation levels, evidence is conflicting and further research is needed. **Aim:** The purpose of this cross-sectional observational study was to assess the relationships between sleep quality and high intensity physical activity with respect to how each lifestyle behavior associates with CVD risk factors and systemic inflammation in a convenience sample of 106 male and female adults, ages 18-25 years. **Methods:** Measurements included lifestyle behaviors (sleep quality, Pittsburgh Sleep Quality Index; reported frequency/intensity of physical activity; reported preference for diet and physical activity, Healthy Behavior Index), CVD risk factors such as anthropometrics (body mass index (BMI), percent body fat, blood pressure) and serum lipids (total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides, total cholesterol-to-HDL-cholesterol ratio), and serum inflammatory measures (C-reactive protein (CRP), cortisol, leptin, insulin). Sleep quality was assessed using the validated Pittsburg Sleep Quality Index, while physical activity was assessed with an open-ended, self-reported format. **Results:** Nearly 30% of the sample was overweight or obese, while nearly 35% of the sample had borderline or high blood pressure. In bivariate association, greater frequency of physical activity was associated significantly with lower levels of leptin and insulin: leptin was most negatively correlated with total physical activity, while insulin was most negatively correlated with the combination of diet and physical activity. Neither high intensity physical activity nor sleep quality was significantly correlated with inflammation as determined by CRP. In terms of CVD risk factors, greater frequency of total physical activity was associated significantly with increased BMI, while greater frequency of physical activity at moderate and high intensities was associated significantly with lower triglycerides. Sleep behaviors displayed no significant association with CVD risk factors. **Conclusion:** This sample of young adults had CVD and inflammatory risks that could be reduced with appropriate lifestyle behavior such as adequate physical activity, but not sleep quality.

1. Introduction

Inflammation exerts a myriad of effects on the body ranging from beneficial to detrimental. The key is to maintain balance. Inflammation is a part of the body's natural immune response that protects against acute infection (Ranjbaran, Keefer, Stepanski, Farhadi, & Keshavarzian, 2007). Conversely, elevated inflammation is the common denominator in a variety of chronic conditions prevalent among Americans: obesity, insulin resistance, type 2 diabetes mellitus, hypertension, metabolic syndrome, rheumatoid arthritis, cardiovascular disease (CVD), and even depression (Esser, Legrand-Poels, Piette, Scheen, & Paquot, 2014; Pearson et al., 2003; Shanahan, Freeman, & Bauldry, 2014). For cardiovascular disease, inflammation can disrupt the serum lipid metabolism, elevating plaque-forming lipids and lowering beneficial lipids (Esteve et al, 2005). As of 2012, 69% of adults in the United States are either overweight or obese (about half of these adults are classified as obese), while the number of adults diagnosed with CVD (the leading cause of mortality in the U.S.) is 26.6 million, 11.3% of adults (National Center for Health Statistics, 2014). While these numbers are concerning, there is evidence that maintaining relatively low levels of inflammation is associated with longevity (Arai et al., 2015).

Although long-term excessive inflammation can lead to the progression of many diseases (Esser et al., 2014; Pearson et al., 2003; Shanahan et al., 2014), the specific environmental cues that trigger the inflammatory response in humans is under debate and requires further research. For example, sleeping for a sufficient number of hours each night and engaging in regular physical activity is associated with desirable health and decreased risk of metabolic syndrome, respectively (Carroll, Irwin, Stein Merkin, & Seeman, 2015; Fruge et al., 2015). Additionally, both sleep and physical activity can potentially impact the amount of inflammation in the body, but the evidence is conflicting.

Physical activity can be both an inflammatory and an anti-inflammatory force. Physical activity can induce the release of inflammatory cytokines during and immediately following physical activity. Acute physical activity has been seen to produce pro-inflammatory cytokines, and this response is proportional to perceived intensity (Nieman et al., 2012; Zwetsloot, John, Lawrence, Battista, & Shanely, 2014). On the contrary, long-term physical activity over the course of a decade is associated with lower levels of C-reactive protein (CRP)—the most commonly measured inflammatory biomarker in the body (Hamer, et al., 2012), independent of levels of adiposity, a confounding variable since adipose tissue can release pro-inflammatory cytokines (Nishimura, Manabe, & Nagai, 2009). However while a number of studies suggest physical activity impacts inflammation (Hamer, et al., 2012; Kadoglou et al., 2007; Nieman et al., 2012; Zwetsloot et al., 2014), others found no significant association (Christiansen, Paulsen, Bruun, Pedersen, & Richelsen, 2010; Devries et al., 2008) despite increased cardiorespiratory fitness. It is suggested that weight loss alone (Hulver et al., 2002) elicits an anti-inflammatory effect, while exercise without weight loss (Devries et al., 2008) has no effect; however, it is possible that higher intensities of physical activity may be necessary to evoke changes in systemic inflammation. Therefore, it is important to consider intensity level when determining physical activity level for the purpose of maintaining healthy inflammatory levels.

Regarding sleep, there are also inconsistencies between studies, particularly with respect to the link between sleep *duration* and inflammation. One study claimed that only longer durations of sleep are associated with significantly increased levels of CRP (Dowd, Goldman, & Weinstein, 2011), while another asserted that extreme durations of sleep, whether short or long, are associated with elevated CRP levels (Grandner, et al., 2013).

Because of the conflicting evidence regarding the association between sleep duration and CRP levels, it is possible that sleep *quality* may be more strongly linked to the levels of abnormal inflammatory markers. Sleep quality encompasses many aspects of sleep: personal perception of sleep quality, ease or difficulty falling asleep, sleep duration, number of interruptions throughout the night, extent of restfulness upon awakening, and degree of function during the day (Wilson, et al., 2015). Some studies assert that poor sleep *quality,* as opposed to inadequate sleep duration, may be associated with elevated levels of CRP (Okun, Coussons-Read, & Hall, 2009; Wilson et al., 2015). Other studies found this association for females only (Prather, Epel, Cohen, Neylan, & Whooley, 2013; Suarez, 2008). Another study found that CRP was not associated with sleep quality, but rather longer durations of sleep (Dowd, Goldman, & Weinstein, 2011).

While sleep and regular physical activity have been seen in some studies to independently influence inflammation levels, further research is necessary to confidently establish a relationship. Furthermore, how both sleep and exercise together affect inflammatory markers has received minimal attention. Specifically, how sleep *quality*, as opposed to quantity, and *high* intensity exercise together impact systemic inflammation requires further research. Given the multitude of chronic diseases that arise from or are impacted by elevated inflammatory levels, understanding the combined effect of sleep and exercise on inflammation can provide insight into the onset, progression, and treatment of these common, yet potentially preventable conditions.

In addition, there is a current necessity to shift the implementation of health care services in the United States from a specialized and reactionary model to a preventative model. Evaluating how key lifestyle factors such as exercise and sleep influence inflammation can play an important role in determining an effective, proactive approach to the delivery of health care with respect to prevention of chronic conditions. Using lifestyle factors as opposed to pharmacological agents as an approach to control inflammation can not only save money, but also improve health outcomes on both an individual and national basis. For example, the United States spent $6,401 per capita on heath care costs in 2005, more than any other country in the world, and about seventy percent of these costs are attributed to the treatment of chronic conditions (Shi & Singh, 2013).

Only about half of American adults in 2013 met the minimum weekly requirements of at least one-hundred and fifty minutes of moderate intensity aerobic exercise, seventy-five minutes of vigorous aerobic exercise, or a comparable combination (National Center for Health Statistics, 2014). Also, only about fifty-eight percent of American adults get the recommended duration of 7-9 hours of sleep each night on workdays. Those who reported higher health quality were more likely to report excellent sleep quality and reported getting a half hour more of sleep on average (Hirshkowitz, et al., 2013; Roehrs, et al., 2013). Furthermore, vigorous exercisers (exercising with hard physical effort such as running, swimming, competitive sports, or cycling, for at least ten minutes in the past seven days) report better sleep quality, suggesting a link between sleep and exercise, with notable differences between exercise intensities (Hirshkowitz, et al., 2013). If more individuals were to engage in adequate exercise (especially high intensity exercise) and took measures to improve their sleep quality, given that these two behaviors decrease inflammation, then it is reasonable to hypothesize that a decrease in the prevalence of chronic diseases, and a parallel reduction in medical expenditure, might ensue.

The present study explores the relationships between sleep quality, high intensity exercise, and inflammation and CVD risk factors among a young adult population between the ages of eighteen and twenty-five. Children adopt lifestyle habits from their parents and have minimal autonomy, while the elderly are limited in their ability to exercise vigorously without injuring themselves. Therefore, it is not as pertinent to include these individuals in studies pertaining to the interplay between exercise, sleep, and inflammation. Chronic diseases tend to develop gradually over time as a result of the aggregate effects of inflammation due to undesirable lifestyle habits; this may be one of the reasons why heart disease is more prevalent among older adults (Hamer, et al., 2012). Younger adults may benefit from measures that help prevent damage to their bodies with appropriate lifestyle choices and behavioral habits.

The present study aimed to extend the research on how sleep quality and high intensity physical activity influence inflammation and CVD risk factors in young adults. The hypotheses in the present study were the following: high intensity exercise and good sleep quality each should be associated with more favorable CRP, serum lipids, blood pressure and adiposity, and poor sleep quality and lower frequency of high intensity physical activity will be positively associated with these risk factors.

2. Methods

2.1 Design and participants

The present study is secondary data analysis of an observational study of 106 college-aged adults. A convenience sample of participants was recruited via email advertisements at the University of Connecticut (UConn) in Storrs, CT. The sample was to serve as a control group for a pilot study carried out in collaboration between the Institute of Living (IOL)/Hartford Hospital (HH) and the University of Connecticut to investigate the risk of metabolic syndrome among psychiatric patients taking second-generation antipsychotics and the roles of stress and inflammation. As such, the exclusion criteria were a history of mental illness diagnoses or treatment as established clinical interviews, the presence of juvenile onset type 1 diabetes, the inability to complete all study components, pregnancy, and other factors that undermined measurements of blood biomarkers or physical examinations. A total of 108 young adults were screened and 2 participants were excluded for not meeting the exclusion criteria. Table 1 provides a description of the study sample.

The University Institutional Review Board (IRB) approved this study prior to the study inception. The participants provided informed and written consent and were paid $50 for their participation.

2.2 Procedures

The study had three main components: clinical interview in *English*, physical assessment, and fasting blood test. The clinical interview was conducted in one 1- to 2-hour session and obtained data on self-reported mental health (stress, anxiety, and depression), addictive (alcohol intake and smoking behaviors), and lifestyle behaviors (dietary intake, physical activity, and sleep quality). The physical examination occurred on the same day as the clinical interview and involved the assessment of adiposity and blood pressure. Participants returned to Koons Hall at the UConn Storrs campus within 48 hours of completing the clinical interview for the fasting blood test after a 12-hour fast. The blood test was used to assess biomarkers of lipid metabolism and the metabolic syndrome.

This specific analysis of this thesis will focus on the relationship between physical activity and sleep quality on inflammation as assessed by blood levels of CRP and other inflammatory biomarkers as they relates to CVD risk factors.

2.3 Physical activity assessment

Average weekly physical activity of each individual was measured through a self-report and self-rated survey, which the researchers in the primary pilot study have created (see Appendix 1 for a sample). The survey included perceived intensity and mode of exercise as well as time spent on a given exercise each week or day. Participants described their perceived intensity for a given mode of exercise as one of three options: "easy/not sweat" (characterized as low intensity), "moderate/sweat a little" (characterized as moderate intensity), or "hard/sweat moderately/a lot" (characterized as high intensity). Weekly minutes of physical activity at each of the intensities (low, moderate, and high) were calculated, as well as total exercise each week including the sum of physical activity minutes at all three intensities. A blank space was provided for subjects to freely report their personal exercise routine.

2.4 Reported Liking for Physical Activity

At the time of measurement, participants completed the Liking Survey. The Liking Survey and similar preference-based surveys have been shown to be valid indicators of health behaviors pertaining to dietary intake (Drewnowski & Hann, 1999; Duffy, Hayes, Sullivan, & Faghri, 2009) with reasonable correlation to reported physical activity (Sharafi et al, 2015). This liking-based health behavior survey was used to generate liking for physical activity as well as the Healthy Behavior Index (HBI). The HBI assessed dietary quality combined with physical activity and sedentary behaviors by utilizing participants' preference for a variety of foods and activities and generating an overall HBI score.

The physical activity group included the following individual items: favorite physical activity, team sports, working up a sweat, exercising alone, gym, exercising with a partner, playing with children, and taking the stairs. The HBI score consists of the weighted average of the physical activity group and a number of diet groups. Each group contained several items pertaining to the group. Diet groups included the following: pleasant, unpleasant, vegetable, salty, high fat protein, fruit, alcohol, fiber, sweets, low fat protein, carbohydrate, bitter beverages, fat, spicy adventurous, and sweet drinks. The group scores were obtained by averaging the liking of every item. Then conceptual weights were assigned to each group (following Dietary Guidelines 2010) before averaging into the total score: physical activity/pleasant/vegetable/low fat protein (+3), fruit/fiber (+2), unpleasant/high fat protein/sweets/sweet drinks (-3), salty/alcohol/fat (-2), and carbohydrate/bitter beverages/spicy adventurous (-1). The total HBI score is the average of the weighted values in each group. Negative HBI scores are indicative of a relatively unhealthy lifestyle, whereas positive HBI scores are indicative of a relatively healthy lifestyle with respect to diet and physical activity. The physical activity group and HBI have shown to be statistically reliable among adults (Sharafi et al, 2015) and children (Gherlone et al, 2016).

2.5 Sleep quality assessment

Sleep quality was measured through a questionnaire referred to as the Pittsburgh Sleep Quality Index (PSQI), which relies on a one-time self-report but evaluates sleep quality in the past month; the PSQI has been established as a reliable indicator for sleep quality to quantitatively identify "good" and "poor" sleepers (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). The PSQI obtains information about an individual's sleep patterns, such as time to fall asleep, duration of sleep, disturbances due to discomfort, and abnormal breathing, as well as other factors attributed to sleep quality, such as difficulty remaining alert throughout the day, or personal (subjective) rating of overall sleep quality.

The PSQI generates a global score (ranging from 0-21) based on the sum of seven component scores (ranging from 0-3) for sleep quality within the past month. The seven component areas are the following: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Low global PSQI scores suggest satisfactory sleep quality, while high scores (global PSQI score >5) are indicative of poor sleep quality, see Appendix 2 for more information regarding types of questions and scoring.

2.6 Physical examination

All physical measurements were repeated three times by the interviewer to assure accuracy. Each measurement was taken before continuing to the next set of measurements. Measurements for height were recorded in centimeters and weight measurements were recorded in pounds; the interviewer also listed and described each participant's clothing during the height and weight measurements to check for accuracy.

The participants' BMI and percent body fat was calculated through height and weight measurements reported by the Tanita™ Bioelectrical Impedance Analyzer (BIA), TBF-300a, which utilized foot-to-foot bioelectrical impedance. The Tanita™ BIA has a patented method that has proven to be an accurate BMI calculator and valid measure of percent body fat (Heydari, Ayatollahi, & Zare, 2011; Houtkooper, Lohman, Going, & Howell, 1996; Kyle et al., 2004). The BIA required input about the participant's gender, age, and level of activity, denoted by "standard" or "athletic", which was determined from the clinical interview assessing participants' intensity and frequency of exercise (see Appendix 1). The cut off for the "athletic" level of activity was 3 hours of total physical activity each week.

Blood pressure readings were taken using an automatic Omron™ digital blood pressure monitor, HEM-712C, which has been evaluated for overall efficacy (Nichols & Crichlow, 2010). All blood pressure readings were taken while participants were sitting, with each of the three readings coming from the same arm unless at least one of the blood pressure readings seemed erroneous, in which case the subsequent blood pressure readings were taken from the opposite arm.

2.7 Biomarkers of CVD and chronic inflammation

Measures of the biomarkers were obtained after participants returned within 48 hours of completing the clinical interview and after a 12-hour fast. Blood samples were delivered to Connecticut Laboratory Partners, Inc. to assess for accuracy. Personal identifiers were removed from blood samples and samples were stored in secure, locked research storage facilities.

CVD Risk Factors: Measures of lipid metabolism included the following: Triglycerides, Total Cholesterol, HDL-cholesterol, estimated LDL-cholesterol (estimated based on calculation from the Friedewald formula) and calculated total cholesterol to HDL-cholesterol ratio (Mshelia at al., 2009; Friedewald, Levy, & Frederickson, 1972). High total cholesterol and low HDL-cholesterol are both risk factors for the development of vascular disease (Emerging Risk Factors Collaboration et al., 2009). High triglycerides and low HDl-cholesterol are associated with increased CRP while oxidized low-density lipoproteins may also have proinflammatory effects (Pearson et al., 2003).

Inflammatory Biomarkers: Inflammatory biomarkers included the following: C-reactive protein, cortisol, leptin, and insulin. Increased CRP is associated with decreased HDL-cholesterol and increased total cholesterol, which increases risk of developing vascular disease (Emerging Risk Factors Collaboration et al., 2009; Johnsson, Panarelli, Cameron, & Sattar, 2014). Elevated CRP, as well as lipid measures, can ultimately lead to ischemic stroke or coronary heart disease(Everett, Kurth, Buring, & Ridker, 2006). Cortisol is known to have anti-inflammatory effects that are ineffective in certain diseases such as coronary artery disease(Nijm, Kristenson, Olsson, & Jonasson, 2007). Leptin is positively associated with CRP (Lowndes et al., 2014; Stakos et al., 2014) and insulin has also been seen to enhance the inflammatory state (Brundage, Kirilcuk, Lam, Spain, & Zautke, 2008). Inflammation as a whole has been implicated in a multitude of disease states such as insulin resistance, type 2 diabetes, obesity, metabolic syndrome, and cardiovascular disease (Esser et al., 2014).

2.8 Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics Version 22 software. Data were evaluated at a significance level of $P \leq 0.05$ unless otherwise noted. Descriptive statistics characterized the means and standard deviations for biological and lifestyle variables for the total sample, as well as for male and female subdivisions. Published national values with a similar age range served as comparisons to the present sample. Sex differences were assessed using the t-test for normally distributed variables, and the Mann Whitney U test for non-normally distributed data. Bivariate relationships were determined using Spearman's Rho correlation to eliminate the need for transformations, unless otherwise noted. A linear regression was used to assess the relationship between the liking of physical activity and minutes of reported physical activity. From the bivariate relationships, a multiple linear regression was conducted to examine the influence of physical activity and sleep behaviors along with other variables on CVD and inflammatory risk factors.

3. Results

A total of 108 participants were interviewed; however, two participants did not receive blood work, resulting in a total sample size of 106 participants. Table 1 shows the descriptive characteristics of the sample, which was predominantly female (roughly 64%), approximately two-thirds white or Caucasian, and about 14% 'minority,' lower than expected based on the 29% minority in the Fall 2015 undergraduate class at the UConn Storrs campus. The age of participants ranged from 18 to 25 years: 55.66% were under 21 years of age, while 44.34% were 21 years and above.

Table 1—Descriptive characteristics of sample (N=106)

Characteristic	Mean ± Standard Deviation			Expected variability in similar-aged population	No. Subjects	% Of Total
	Males	Females	Total			
Gender						
Female					n=68	63.89
Male					n=38	36.11
Age (years) (Range: 18-25 years)	20.45 ± 1.41	20.15 ± 1.36	20.31 ± 1.42	96.8% Fall '14 ugrad: 15-24 yr		
Race						
White/Caucasian					n=71	66.98
Asian/Pacific Islander					n=20	18.87
Hispanic/Latino					n=8	7.55
Black/African American					n=4	3.77
Other, Mixed, & Unspecified					n=3	2.83
% minority				% Minority (Fall '15 ugrad, Storrs) = 29.17		% Minority = 14.15
CARDIOVASCULAR DISEASE RISK FACTORS						
Body Mass Index (BMI) (n=105)[a]	25.17 ± 3.18	22.04 ± 2.67	23.26 ± 3.29	26.69 ± 7.24		
Underweight (<18.5)				3.5%	n=4	3.80
Normal (18.5-24.9)				47.2%	n=70	66.67
Overweight (25-29.9)				24.4%	n=29	27.61
Obesity (30+)				24.9%	n=2	1.90
Percent Body Fat (%)	15.06 ± 6.70	23.42 ± 6.26	20.42 ± 7.55			
Blood Pressure [b]						
Systolic (SBP)	119.64 ± 10.37	105.51 ± 10.52	110.57 ± 12.44	112.95 ± 10.75		
Diastolic (DBP)	70.92 ± 7.58	71.51 ± 8.22	71.07 ± 7.96	63.18 ± 11.32		
Serum lipids [c]						
Total Cholesterol	158.97 ± 27.28	170.44 ± 27.99	166.33 ± 28.15	165.91 ± 33.69		
Est. LDL-cholesterol	89.18 ± 24.71	88.50 ± 25.11	88.75 ± 24.86	93.26 ± 29.20		
HDL-cholesterol	54.87 ± 13.15	64.74 ± 14.49	51.25 ± 12.71	51.34 ± 12.87		

Triglycerides Chol/HDL Ratio	74.95 ± 32.34 3.04 ± 0.81	85.93 ± 3.47 2.74 ± 0.66	81.99 ± 33.33 2.85 ± 0.73	86.46 ± 50.37 3.45 ± 1.08		
INFLAMMATION BIOMARKERS						
C-Reactive Protein (CRP) [d]	0.14 ± 0.22	0.18 ± 0.19	0.16 ± 0.20	0.32 ± 0.61		
Cortisol (n=104) [e]	20.09 ± 1.06	28.20 ± 11.59	25.28 ± 10.75			
Leptin [f]	2.11 ± 1.58	7.28 ± 5.34	5.43 ± 5.03	**Females:** [g] 13.6 ± 0.66 **Males:** [g] 6.0 ± 0.16		
Insulin [h]	8.93 ± 4.55	9.63 ± 4.23	9.38 ± 4.34	14.21 ± 17.00		

a = weight (kg)/height squared (m^2); b = mm Hg; c = mg/dL; d = mg/L, e = µg/dL, f = ng/mL g = Geometric mean ± SEM, h = mIU/mL. NHANES national comparisons ages 18-25: CRP from 2009-2010, Insulin from 2011-2012, Leptin from 1988-1994 (ages 20-29), & all other variables are from 2013-2014 NHANES data. UConn Fall 2015 Undergraduate demographics from: http://www.oir.uconn.edu/Student_Data.html.

3.1 *Descriptive findings – CVD risk factors*

Adiposity: As seen in Table 1, roughly two-thirds of the sample had a normal BMI, while nearly 30% was either overweight or obese. Our sample had lower adiposity relative to the 49.3% of young adults ages 18-25 in the U.S. who were classified as either overweight or obese by the reference 2013-2014 NHANES data (Centers for Disease Control and Prevention (CDC) & National Center for Health Statistics (NCHS)). Males had significantly higher average BMI than did females (25.15 ± 0.50 vs. 22.18 ± 0.35 respectively, $t = -5.01$, $p < 0.001$). Males also had a significantly lower average percent body fat than did females (15.19 ± 1.07 vs. 23.65 ± 0.78 respectively, $t = 6.44$, $p < 0.001$).

Blood Pressure: Of the total sample, 35 had borderline hypertension (systolic blood pressure 120 to 139 mmHg and/or diastolic blood pressure 80 to 89 mmHg) and 2 had high blood pressure (systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg) (Forget et al., 2013). Males also had a significantly higher average systolic blood pressure than did females (119.84 ± 1.65 vs. 105.44 ± 1.25 respectively, $t = -6.91$, $p < 0.001$).

Serum Lipids: Of the total sample, 13 participants had high total cholesterol (>200mg/dL), 6 participants had low HDL-cholesterol (≤40mg/dL), 37 participants had high LDL –cholesterol (≥100mg/mL), and 5 participants had high triglycerides (≥100mg/dL), and 21 participants had a high total cholesterol-to-HDL ratio (≥3.5) (Emerging Risk Factors Collaboration et al., 2009; Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001). There were also some notable sex differences in lipid levels: females had significantly higher average total cholesterol than did males (170.44 ± 3.39 vs. 158.97 ± 4.43 respectively, $t = 2.04$, $p = 0.044$). Females also had significantly higher average HDL-cholesterol than did males (64.74 ± 1.76 vs. 54.87 ± 2.13 respectively, $t = 3.47$, $p = 0.001$), but significantly lower average total cholesterol-to-HDL-cholesterol ratio than did males (1.64 ± 0.02 vs. 1.73 ± 0.037 respectively, $t = -2.01$, $p = 0.047$).

3.2 Descriptive findings – inflammatory biomarkers

Females had significantly higher cortisol levels than did males, after using a square root transformation to obtain normal distribution (5.20 ± 0.13 vs. 4.42 ± 0.12, t= 4.30, $p < 0.001$). Levels of leptin for males and females were both lower than the reference national data, and insulin level for the total sample was lower than the reference national data, see Table 1.

3.3 Descriptive findings – physical activity

Physical activity was recorded for 102 participants, since 4 participants had incomplete physical activity data. As can be seen in Table 2, the variability in physical activity was high – standard deviations were all greater than 180 minutes and interquartile ranges were all greater than 220 minutes across all exercise categories (total, high intensity, moderate intensity, and moderate/high intensity).

Table 2 — Lifestyle characteristics of sample (N=106)

Characteristic	**Mean ± Standard Deviation**			**Expected variability in similar-aged population**	**No. Subjects**	**% Of Total**
	Males	**Females**	**Total**			
PHYSICAL ACTIVITY						
Physical activity (min/week) (n=102) [a]						
Total physical activity	481.94 ± 367.27	314.12 ± 217.03	373.94 ± 289.63			
Low intensity	53.40 ± 119.98	42.69 ± 130.37	46.51 ± 126.27			
Moderate intensity	164.58 ± 200.35	160.50 ± 189.74	161.60 ± 192.60	218.10 ± 267.34		
High intensity	250.63 ± 279.83	110.23 ± 165.28	160.27 ± 222.39	338.05 ± 307.40		
Moderate/high intensity	429.79 ± 338.38	270.73 ± 217.79	327.43 ± 276.21	613.21 ± 511.97		
Physical activity groups (n=102) [b]						
<60 min/week total				14.1%	n=6	5.88
<300 min/week total				53.4%	n=49	50.00
<420 min/week total				74.0%	n=63	62.75
DIET & PHYSICAL ACTIVITY						
Healthy Behavior Index (HBI) [c] **(Range: -100 to +100)**	15.74 ± 30.68	25.63 ± 45.27	21.86 ± 40.61			
Liking of Physical Activity	53.11 ± 19.14	44.57 ± 21.53	47.63 ± 21.02			
SLEEP QUALITY						
Pittsburg Sleep Quality Index (PSQI) Score (Range: 0-21)	4.35 ± 2.73	4.26 ± 2.57	4.32 ± 2.66			
"Poor" (PSQI > 5)					n=28	26.42
"Good" (PSQI ≤ 5)					n=78	73.58
Sleep Quality Self Report [d]						
Very good				19%	n=37	34.91

Fairly good Fairly bad Very bad				57% 19% 5%	n=57 n=11 n=1	53.77 10.38 0.94
Hours of Sleep per Night (n=104) [e] <6 hours 6 – <7 hours 7 – <8 hours 8+ hours	7.28 ± 1.17	7.23 ± 1.13	7.25 ± 1.14	7.11 ± 1.36 9.9% 22.4% 25.1% 42.5%	 n=9 n=22 n=41 n=32	 8.65 21.15 39.42 30.77

a = average minutes each week in the past month, compared to the reference 2013-2014 NHANES data (Centers for Disease Control and Prevention (CDC) & National Center for Health Statistics (NCHS)), matched for age. For the physical activity comparison, we only took into account moderate/vigorous recreational physical activity, as opposed to recreational and work activity combined, since most of the exercise reported in this study was recreational; b = Physical activity groups are for all types/intensities, compared to the reference 2013 High School Youth Risk Behavior Survey in CT (Centers for Disease Control and Prevention (CDC) & National Center for Health Statistics (NCHS)); c = Healthy Behaviors Index is based on diet and physical activity; d = compared to the 2013 *Sleep in America*® Poll: Exercise and Sleep, Summary of Findings (National Sleep Foundation: https://sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2013-exercise-and-sleep); e = compared to the 2013-2014 NHANES data, matched for age (Centers for Disease Control and Prevention (CDC) & National Center for Health Statistics (NCHS)).

Males also reported significantly higher average weekly minutes of total physical activity than did females, after using a square root transformation to obtain normal distribution (19.51 ± 1.38 vs. 16.39 ± 0.83 respectively, $t= -2.06$, $p= 0.042$). A Mann-Whitney U test determined that males and females had significantly different distributions for weekly minutes of high intensity exercise ($p=0.016$) as well as moderate and high intensity exercise combined ($p=0.017$).

Regarding the liking of physical activity, males reported a trend towards greater average liking for physical activity than did females (52.45 ± 3.10 vs. 44.58 ± 2.57 respectively, $t= -1.90$, $p= 0.06$). Liking of physical activity had a strong positive correlation with weekly minutes of total physical activity (0.268, $p=0.007$), minutes of weekly high intensity physical activity (0.553, $p < 0.001$), as well as weekly minutes of moderate and high intensity physical activity combined (0.382, $p < 0.001$). Figure 1 a-c depicts this relationship for the total sample. No correlation existed between liking of physical activity and minutes of moderate intensity physical activity each week.

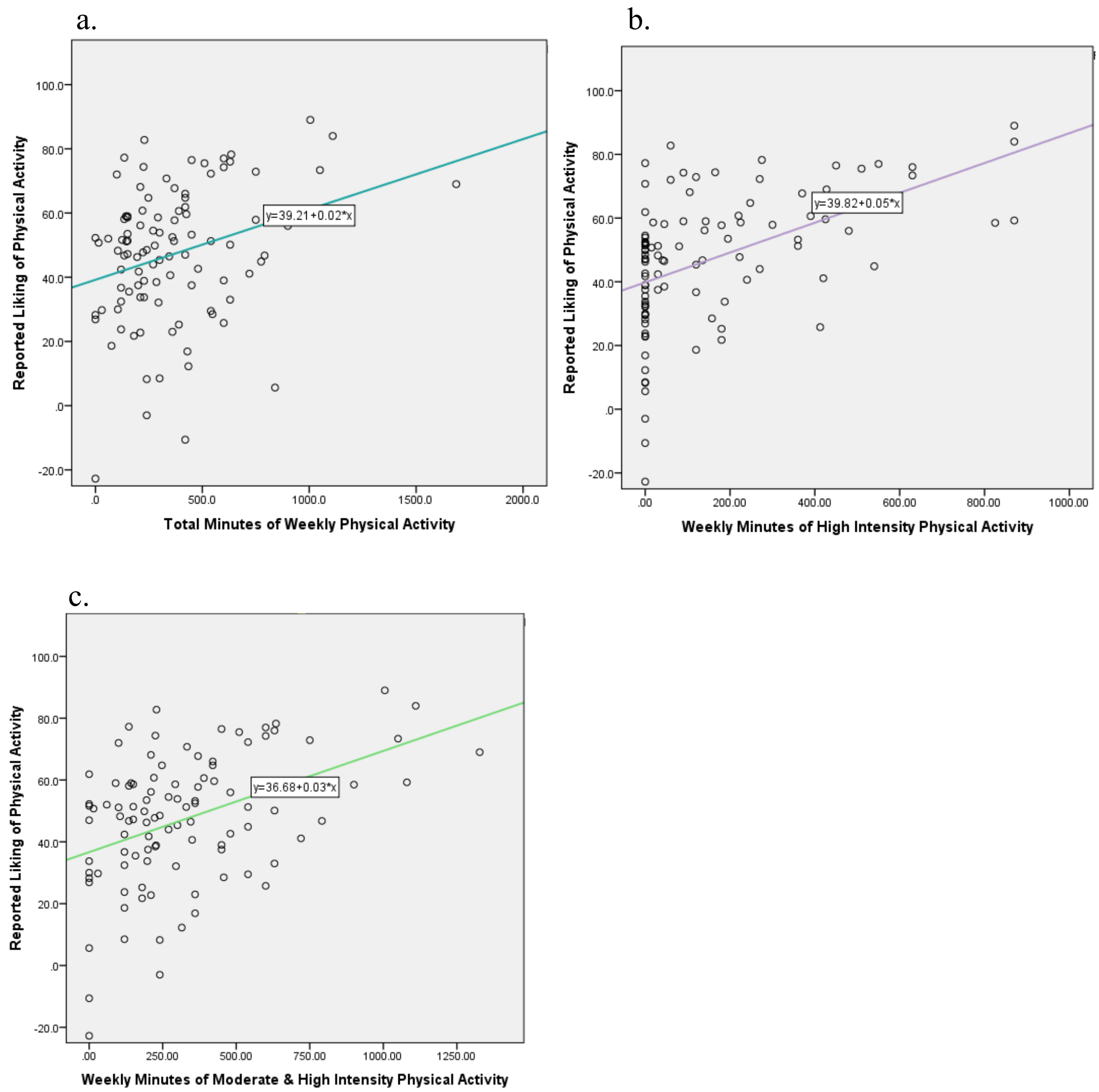

Fig. 1. Correlation between reported liking of physical activity (from the HBI) and actual minutes of physical activity (n=102) at different intensities: (a) total physical activity at all intensities, (b) only high intensity physical activity, and (c) moderate and high physical activity combined.

Many students reported no physical activity or limited physical activity, while some reported extreme amounts of physical activity. Approximately 74% of the sample met the recommendations under the *2008 Physical Activity Guidelines for Adults* (Schoenborn & Stommel, 2011) for 150 minutes each week of moderate or high physical activity, although physical activity was not distinguished by aerobic and anaerobic.

Figure 2 a-d shows the distribution for weekly minutes of physical activity at different intensities. Less than a quarter of participants reported affirmative regarding low intensity physical activity under the “easy/not sweat” category, even though a typical college student walks to classes regularly.

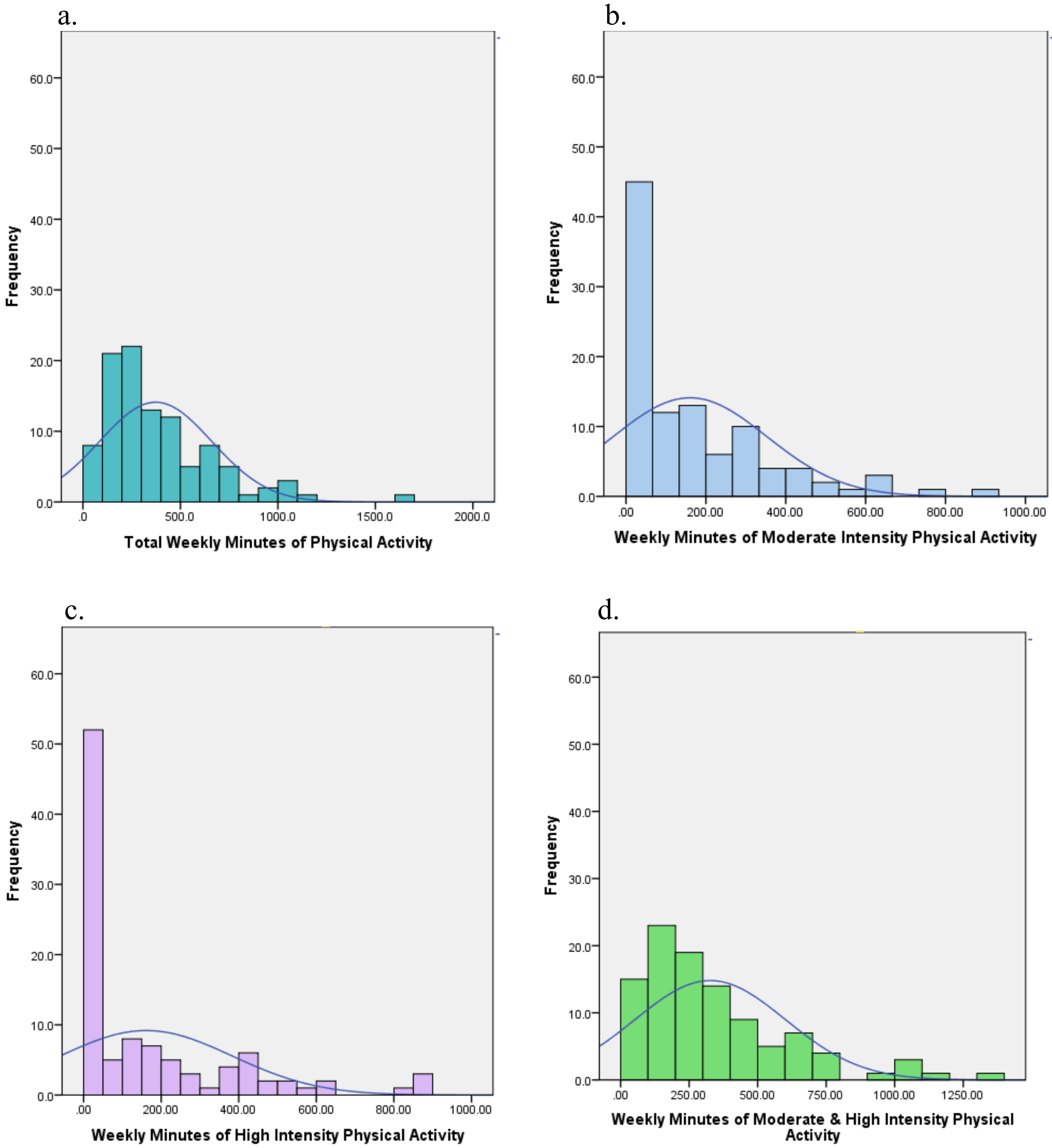

Fig. 2. Distribution of physical activity (minutes/week) at different intensities: (a) total physical activity at all intensities, (b) only moderate intensity physical activity, (c) only high intensity physical activity, and (d) moderate and high physical activity combined.

As shown in Figure 3, approximately 41% of the sample reported a lack of participation in high intensity physical activity, while 47% reported partaking in at least 75 minutes each week of high intensity physical activity. Of those individuals reporting at least of 75 minutes, 25.75% were in the 75-150 minute range, 29.78% were in the 151-300 minute range, and 44.68% were in the 300+ minute range.

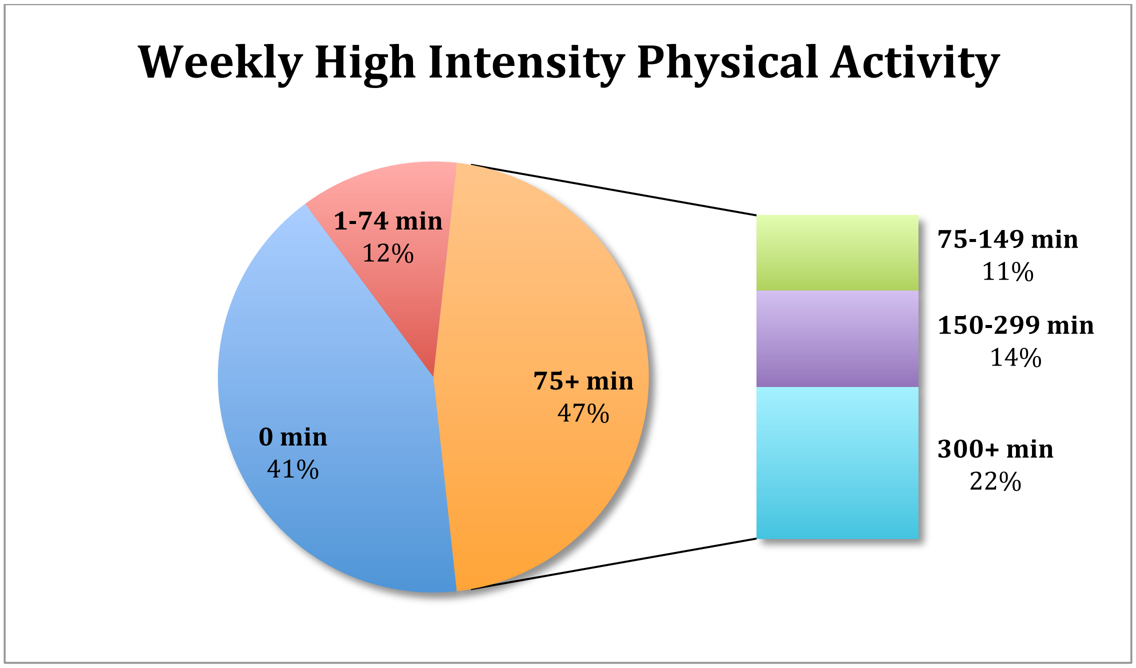

Fig. 3. Percentage (%) of participants (n=102) partaking in a given amount of weekly minutes (min) of high intensity exercise.

Approximately 30 individuals (28% of the sample) were taking action to lose weight through either exercise alone (20.75% of the sample) or through a combination of diet and exercise (7.54% of the total sample); of these individuals, only 40% had a BMI categorized as greater than normal.

3.4 Descriptive findings – sleep quality

Sleep quality scores had minimal variability, with nearly three-quarters of participants falling under the "good" sleep quality category, and over a quarter of participants falling under "poor" sleep quality as determined from the global PSQI score, see Figure 4. Despite the fact that 26% of participants were categorized as having "poor" sleep quality, only 11% of respondents reported a subjective sleep quality of "fairly bad" or "very bad", suggesting a possible discrepancy between actual and perceived sleep quality. Figure 5 depicts exactly where this discrepancy falls. There was a discrepancy between actual and perceived sleep quality in 17% of respondents, with most discrepant participants reporting "fairly good" sleep quality while actually having poor sleep quality, despite the fact that subjective sleep quality is one of the component scores factoring into the PSQI global score.

As seen in Table 2, about 69.23% of the sample was not getting an average of at least 8 hours of sleep each night, which is comparable to the national proportion of 68.3% of high school students not getting enough sleep on a typical school night, according to the 2013 High School Youth Risk Behavior Survey (Centers for Disease Control and Prevention (CDC) & National Center for Health Statistics (NCHS)).

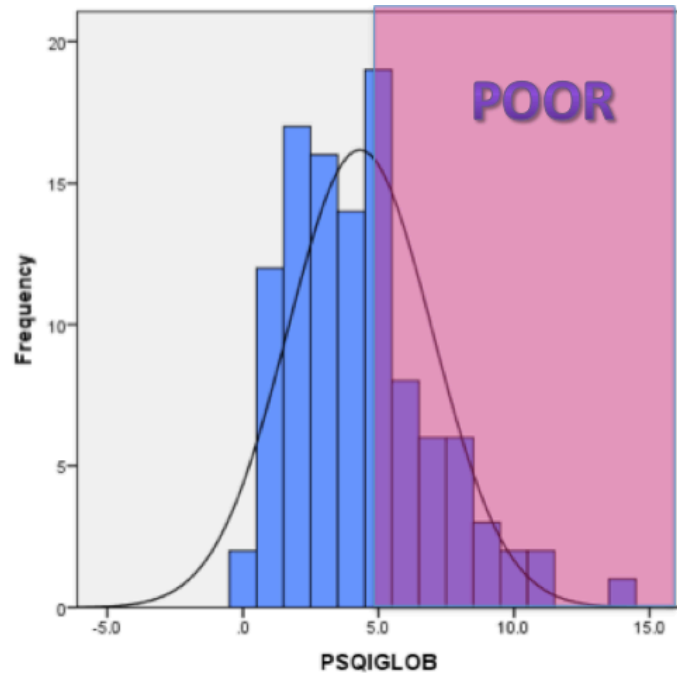

Fig. 4. Distribution of sleep quality from the PSQI global score.

	Good *Actual* Sleep Quality	**Poor *Actual* Sleep Quality**	
Good *Subjective* Sleep Quality	38 “very good” 39 “fairly good” n=77 (72.64%)	1 “very good” 16 “fairly good” n=17 (16.04%)	n=94 (88.68%)
Poor *Subjective* Sleep Quality	1 “fairly bad” n=1 (0.94%)	10 “fairly bad” 1 “very bad” n=11 (10.38%)	n=12 (11.32%)
	n=78 (73.58%)	n=28 (26.42%)	N=106 (100.00%)

Fig. 5. Discrepancy (yellow) between reported subjective sleep quality and actual sleep quality as determined from the PSQI.

3.5 Relationship between physical activity and sleep quality

Only moderate intensity physical activity showed significant positive correlations with sleep duration (0.234, p=0.019) and sleep quality (-0.244, p=0.013). On the other hand, high intensity physical activity tended toward a significant negative correlation with sleep duration (-0.196, p=0.051).

3.6 Relationship between physical activity, CVD risk factors, and inflammation biomarkers

CVD risk factors: Moderate/high intensity physical activity tended towards a significantly negative correlation with percent body fat (-0.178, p=0.074). On the other hand, BMI was positively correlated with total physical activity (0.242, p=0.015) and liking of physical activity (0.200, p=0.045).

Systolic blood pressure was positively correlated with total physical activity (0.236, p=0.017) and moderate/high intensity physical activity (0.247, p=0.012). Diastolic blood pressure was negatively correlated with high intensity physical activity (-0.199, p=0.045) and HBI score (-0.227, p=0.022).

Regarding serum lipids, the cholesterol-to-HDL-cholesterol ratio was negatively correlated with HBI score (-0.195, p=0.049). Triglycerides were significantly negatively correlated with moderate/high intensity physical activity (-0.231, p=0.019) and HBI score (-0.224, p=0.024) and tended towards a significant negative correlation with total physical activity (-0.191, p=0.055) and high intensity physical activity (-0.178, p=0.073).

Inflammation biomarkers: Physical activity significantly correlated with leptin and insulin, but not cortisol and CRP. In order of highest to lowest significance, leptin was negatively correlated with total physical activity (-0.327, p=0.001), moderate/high intensity physical activity (-0.299, p=0.002), and high intensity physical activity (-0.211, p=0.033). In order of decreasing significance, insulin was negatively correlated with HBI score (-0.281, p=0.004), moderate/high physical activity (-0.206, p=0.038), and total physical activity (-0.200, p=0.043). In standard linear regression analysis, the HBI and percent body fat contributed to explaining significant variability in insulin ($r=0.427$, $p<0.001$). Both HBI and percent body fat significantly contributed uniquely to this model (-0.229, p=0.002 and 0.301, p=0.002, respectively).

3.7 Relationship between sleep quality, CVD risk factors, and inflammation biomarkers

Sleep quality did not associate with any of the CVD risk factors or any of the inflammatory biomarkers in either sex, or in the total sample. Sleep *duration* only tended towards a positive correlation with CRP (0.173, p=0.084).

3.8 Summary models of bivariate relationships

Figure 6 and Figure 7 depict the relationships between physical activity, sleep behavior, CVD risk factors, and inflammatory biomarkers. Diastolic blood pressure was inversely related to physical activity, whereas systolic blood pressure was positively related to physical activity. The HBI was negatively associated with the cholesterol-to-HDL-cholesterol ratio. Inflammatory biomarkers, particularly leptin and insulin, were mostly associated with physical activity at various intensities. Sleep behavior was not correlated with any CVD risk factor or biomarker.

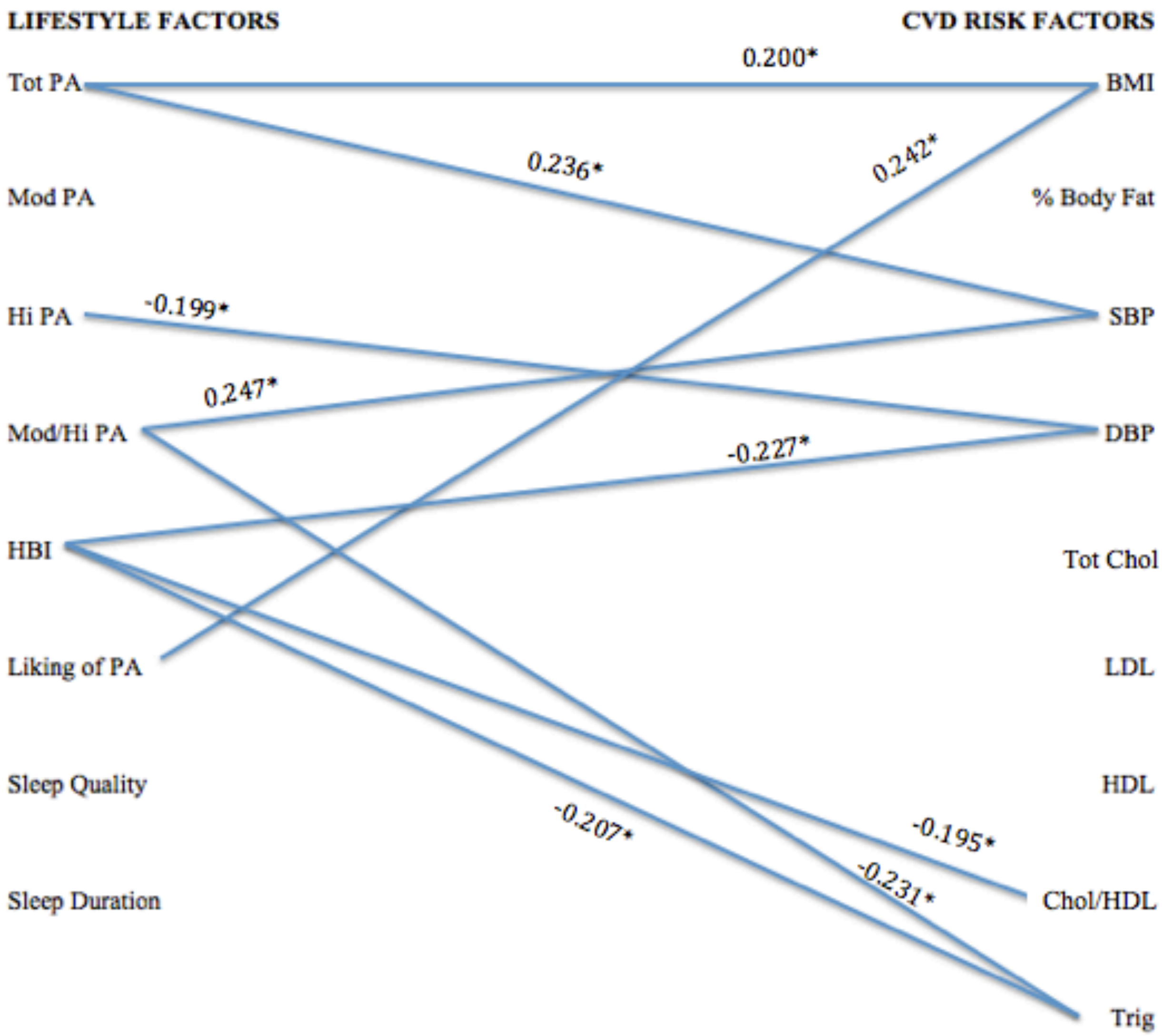

Fig. 6. Potential model of association between lifestyle factors (physical activity and sleep) and CVD risk factors. Tot PA = total minutes/week of physical activity (all intensities), Mod PA = minutes/week of moderate intensity physical activity, Hi PA = minutes/week of high intensity physical activity, Mod/Hi PA = minutes/week of moderate and high intensity physical activity combined, HBI = Healthy Behavior Index, BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, Tot Chol = total cholesterol, LDL = LDL-cholesterol, HDL = HDL-cholesterol, Chol/HDL = cholesterol-to-HDL-cholesterol ratio, Trig = triglycerides. Levels of significance: * $P < 0.05$, ** $P < 0.01$.

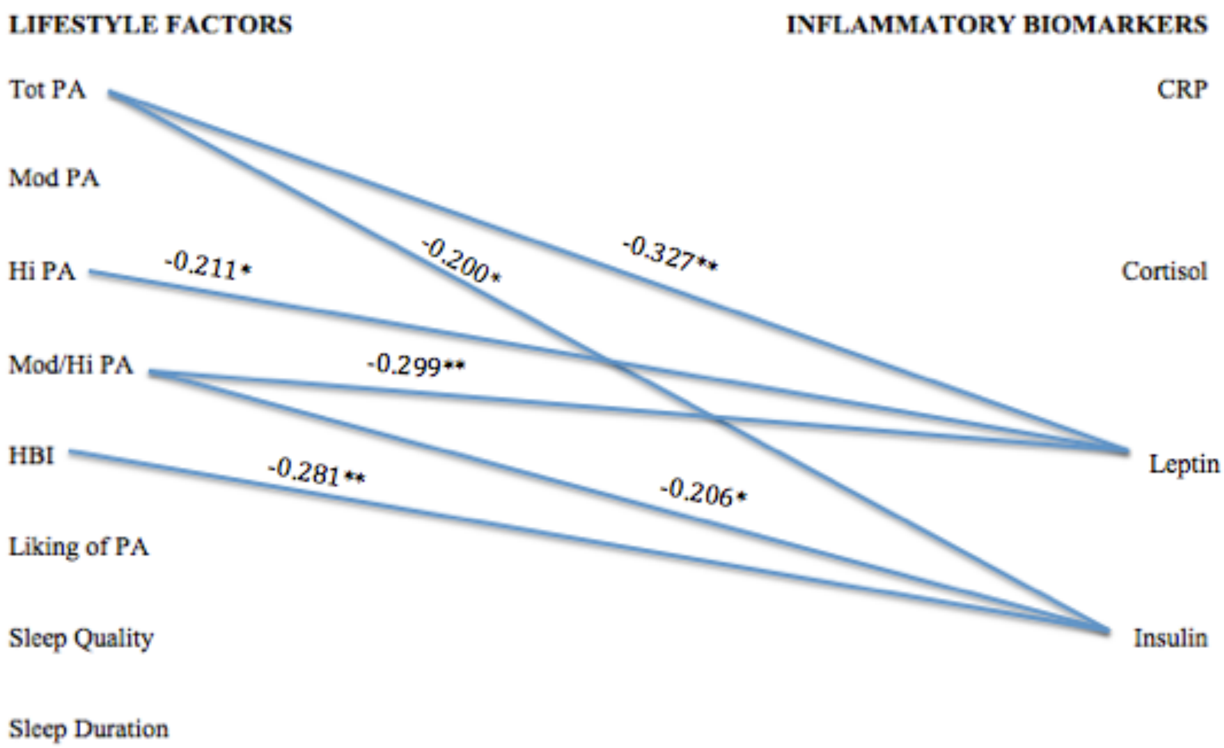

Fig. 7. Potential model of association between lifestyle factors (physical activity and sleep) and inflammatory biomarkers. Tot PA = total minutes/week of physical activity (all intensities), Mod PA = minutes/week of moderate intensity physical activity, Hi PA = minutes/week of high intensity physical activity, Mod/Hi PA = minutes/week of moderate and high intensity physical activity combined, HBI = Healthy Behavior Index. Levels of significance: * P < 0.05, ** P < 0.01.

4. Discussion

This was an exploratory study to describe and examine lifestyle factors that associate with CVD risk factors and inflammation. In the present sample, high intensity physical activity and sleep quality were not significantly correlated with CRP. Leptin was negatively correlated with total physical activity and high intensity physical activity. Insulin was negatively correlated with HBI score and total physical activity. Sleep quality and sleep duration did not significantly correlate with any of the CVD risk factors or inflammatory biomarkers.

The fact that our study found no associations between CRP and any intensity of physical activity is contrary to some previous studies (Hamer et al, 2012; Kadoglou et al., 2007). However, it is important to note that the participants in those studies had a mean age of about 49 years and 61 years, respectively, much older than the mean age of 20 years in our sample. The young age in the present study may explain the lack of associations found with CRP, since inflammation tends to associate with age-related conditions (Franceschi et al., 2007). It is possible that inflammation increases as damage accumulates over time as a result of poor lifestyle behaviors. Additionally, Kadoglou et al., 2007's study had all overweight participants with type 2 diabetes mellitus completing an aerobic exercise intervention of 150 minutes each week at moderate and high intensity. Only 27% of the participants in the present study were overweight, and physical activity was not distinguished by aerobic and anaerobic, although 74%

of the participants were getting at least 150 minutes each week of moderate or high intensity physical activity. It is possible that aerobic physical activity elicits a greater improvement in inflammation. It is also possible that the inflammatory response to lifestyle behaviors differs in individuals with certain disease states compared to healthy individuals.

This study also found no associations between CRP and sleep quality, contrary to some previous studies (Okun et al., 2009; Prather et al., 2013; Wilson et al., 2015). The latter two studies had participants with inflammatory conditions or cardiovascular complications and did not use the PSQI global score to assess sleep quality. Prather et al., 2013 used only the PSQI subjective sleep quality component, but our study found discrepancies between subjective sleep quality and actual sleep quality as defined by the PSQI global score (see Fig. 5), so it is difficult to compare those results with those in the present study. The study by Okun et al, 2009 had healthy participants with a mean age of 28 years and used the PSQI global score to assess sleep quality, but all participants were female, so it is also difficult to compare directly to our study in which 36% of the participants were males.

Although high intensity physical activity and sleep quality were not significantly related to CRP in this study, these two lifestyle factors were significantly related to other biomarkers and characteristics associated with increased CRP, such as elevated blood pressure, high BMI, low HDL-cholesterol, and high triglycerides (Fontes et al., 2013; Pearson et al., 2003; Sesso, Wang, Buring, Ridker, & Gaziano, 2007; Steptoe, Hamer, & Chida, 2007; Suarez, 2004). It is possible that high intensity physical activity and sleep quality indirectly affect inflammation via mechanisms not reflected by increases in CRP. Further studies should be performed to establish this potential indirect relationship. In the present study, physical activity was correlated with leptin and insulin but not CRP, although leptin has been shown to produce CRP in coronary arteries (De Rosa et al., 2009), and insulin has also been shown to stimulate the inflammatory response (Brundage et al., 2008). It is possible that lifestyle behaviors affect leptin and insulin at a relatively faster rate than CRP. It may take more time to induce changes in CRP.

It is well known that high total cholesterol and low HDL-cholesterol are both risk factors for the development of CVD (Emerging Risk Factors Collaboration et al., 2009); the same study also asserted that increased CRP is associated with decreased HDL-cholesterol, and increased total cholesterol at levels of CRP below 10mg/L (Johnsson et al., 2014). While all participants in the present study had CRP levels below 10mg/L, no positive correlation was found between CRP and total cholesterol.

The liking for physical activity was strongly and positively correlated with actual minutes of physical activity. Harnessing the liking survey as opposed to reported physical activity may simplify data collection while maintaining similar results. Similar dietary preference surveys have been shown to be valid indicators of health behaviors regarding dietary intake (Drewnowski & Hann, 1999; Duffy, Hayes, Sullivan, & Faghri, 2009) with reasonable correlation to reported physical activity (Sharafi et al, 2015).

One strength of the present study is that it introduces a novel concept by examining the interaction between high intensity exercise and sleep quality, two lifestyle factors that are not typically joined together in analyses of health risks such as inflammation. This study also accounted for individual dietary preference, since diet has been seen to affect inflammation directly (Giugliano, Ceriello, & Esposito, 2006) or indirectly through protecting the anti-inflammatory effects of cortisol (Ruijters, Haenen, Willemsen, Weseler, & Bast, 2016). Another strength is that participants were free to go about their daily lives as they normally would; this, along with minimal exclusion criteria, made our study results widely generalizable to the general population.

The limitations of this study must also be addressed. One limitation includes the small sample size (N=106) with unequal numbers of males and females, making it difficult to compare results between the sexes in our study, and also to compare with prior studies. The observational design with one-time blood samples was also a weakness that restricted the results to non-causal associations at one point in time instead of causal, long-term effects. Another limitation of the design was data collection via interview, which, while necessary, may have made participants less likely to provide honest answers out of embarrassment. Additionally, the open format of entering weekly physical activity minutes rendered the data subject to ambiguity that could have resulted in the loss of study participants as well as over- or under-estimation of participants' physical activity. This study also did not distinguish between modes of exercise such as resistance and endurance training, which could have be a useful and important distinction. Lastly, the number of individuals with poor sleep quality was relatively low, so we could not assess the combined effect of sleep quality and physical activity on inflammation.

Future interventional and longitudinal studies should be performed in order to establish how high intensity physical activity and sleep quality interact to affect chronic systemic inflammation. The right lifestyle may be an effective means to prevent elevated inflammation in young adults, or decrease previously elevated inflammation in older adults. Future studies should have equal numbers of males and females to explore potential sex differences inflammatory responses to lifestyle behaviors. A within-subjects design is also preferable to control for the following confounding variables on inflammation: blood pressure, BMI, diabetes mellitus, HDL-cholesterol, triglycerides, weight loss, the use of estrogen or progesterone hormones, smoking status, chronic infections, or conditions such as rheumatoid arthritis characterized by chronic inflammation (Pearson et al., 2003). A within-subjects design may also enhance clinical applicability by resembling a personalized medicine approach. It may be of interest to measure a wide array of both pro- and anti-inflammatory cytokines in circulation, adipose tissue, and skeletal muscle for a more global perspective on this complex issue. Accounting for confounders over an extended period of time may help to better understand how sleep quality and physical activity as various intensities interact to impact chronic inflammation.

It is important to carry out further studies in a college-aged population, not only because the number of studies focusing on this age group is limited, but also since this age group is at risk for above average weight gain (Hovell, Mewborn, Randle, & Fowler-Johnson, 1985). One study with a predominantly female sample with a mean age of 20.5 years and average BMI of 23.3 kg/m^2 (comparable demographics to the present study) and showed how, despite the normal BMI at baseline for the majority of the sample, poor diet led to a greater risk of weight gain after a four-year follow-up (Forget et al., 2013). Furthermore, adherence to the *2008 Physical Activity Guidelines for Adults* is associated with lower all-cause mortality for adults and even lower mortality for adults with comorbidities, regardless of age or obesity (Schoenborn & Stommel, 2011). Also, sleep disturbances in a college-aged population were seen to significantly impact weight (Vargas, Flores, & Robles, 2014). The results from these studies suggest that achieving ideal health is linked to adopting healthy lifestyles. Younger people may also have the most to gain from preventative strategies, since establishing healthy behaviors can continue throughout adulthood to maintain overall health.

5. Conclusion

In conclusion, this study investigated the associations between inflammation and other CVD risk factors with lifestyle factors such as physical activity and sleep quality. Hopefully, our inquiry and results will stimulate further research in this area which will ultimately allow physicians to effectively advise and treat patients of all ages with high inflammation who are at risk for other conditions, such as obesity, cardiovascular disease, and depression (Shanahan, Freeman, & Bauldry, 2014), and provide them with formal recommendations regarding sleep quality and physical activity in order to elicit reductions in inflammation levels and improve overall health. Researching the effects of high intensity physical activity and sleep quality on inflammation may be critical in unearthing novel ways to evoke changes in the inflammatory profile, which may in turn benefit overall population health, the ultimate goal.

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Appendix

Appendix 1: Self-Rated/Reported Exercise

Type	How hard?	Time Spent?	
		Minutes	Per day or week
1.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week
2.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week
3.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week
4.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week
5.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week
6.	○Easy/not sweat ○Moderate/sweat a little ○Hard/sweat a lot		○Day ○Week

Appendix 2: Pittsburgh Sleep Quality Index (PSQI)

Appendix. Pittsburgh Sleep Quality Index (PSQI)

Name ______________ ID # ________ Date ________ Age ______

Instructions:

The following questions relate to your usual sleep habits during the past month *only*. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?
   USUAL BED TIME ________
2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?
   NUMBER OF MINUTES ________
3. During the past month, when have you usually gotten up in the morning?
   USUAL GETTING UP TIME ________
4. During the past month, how many hours of *actual sleep* did you get at night? (This may be different than the number of hours you spend in bed.)
   HOURS OF SLEEP PER NIGHT ________

For each of the remaining questions, check the one best response. Please answer *all* questions.

5. During the past month, how often have you had trouble sleeping because you...

(a) Cannot get to sleep within 30 minutes

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(b) Wake up in the middle of the night or early morning

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(c) Have to get up to use the bathroom

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(d) Cannot breathe comfortably

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(e) Cough or snore loudly

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(f) Feel too cold

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(g) Feel too hot

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(h) Had bad dreams

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(i) Have pain

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(j) Other reason(s), please describe ________________________________

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

6. During the past month, how would you rate your sleep quality overall?

Very good ____
Fairly good ____
Fairly bad ____
Very bad ____

7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all ____
Only a very slight problem ____
Somewhat of a problem ____
A very big problem ____

10. Do you have a bed partner or roommate?

No bed partner or roommate ____
Partner/roommate in other room ____
Partner in same room, but not same bed ____
Partner in same bed ____

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

(a) Loud snoring

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(b) Long pauses between breaths while asleep

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(c) Legs twitching or jerking while you sleep

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(d) Episodes of disorientation or confusion during sleep

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

(e) Other restlessness while you sleep; please describe ________________________________

____

Not during the past month ____ Less than once a week ____ Once or twice a week ____ Three or more times a week ____

Scoring Instructions for the Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) contains 19 self-rated questions and 5 questions rated by the bed partner or roommate (if one is available). Only self-rated questions are included in the scoring. The 19 self-rated items are combined to form seven "component" scores, each of which has a range of 0-3 points. In all cases, a score of "0" indicates no difficulty, while a score of "3" indicates severe difficulty. The seven component scores are then added to yield one "global" score, with a range of 0-21 points, "0" indicating no difficulty and "21" indicating severe difficulties in all areas.

Scoring proceeds as follows:

Component 1: Subjective sleep quality

Examine question #6, and assign scores as follows:

Response	Component 1 score
"Very good"	0
"Fairly good"	1
"Fairly bad"	2
"Very bad"	3

Component 1 score: ______

Component 2: Sleep latency

1. Examine question #2, and assign scores as follows:

Response	Score
≤ 15 minutes	0
16-30 minutes	1
31-60 minutes	2
> 60 minutes	3

Question #2 score: ______

2. Examine question #5a, and assign scores as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Question #5a score: ______

3. Add #2 score and #5a score

Sum of #2 and #5a: ______

4. Assign component 2 score as follows:

Sum of #2 and #5a	Component 2 score
0	0
1-2	1
3-4	2
5-6	3

Component 2 score: ______

Component 3: Sleep duration

Examine question #4, and assign scores as follows:

Response	Component 3 score
> 7 hours	0
6-7 hours	1
5-6 hours	2
< 5 hours	3

Component 3 score: ______

Component 4: Habitual sleep efficiency

(1) Write the number of hours slept (question # 4) here: ______

(2) Calculate the number of hours spent in bed:

Getting up time (question # 3): ______

− Bedtime (question # 1): ______

Number of hours spent in bed: ______

(3) Calculate habitual sleep efficiency as follows:

(Number of hours slept/Number of hours spent in bed) × 100 = Habitual sleep efficiency (%)

(______/______) × 100 = ______%

(4) Assign component 4 score as follows:

Habitual sleep efficiency %	Component 4 score
> 85%	0
75-84%	1
65-74%	2
< 65%	3

Component 4 score: ______

Component 5: Sleep disturbances

(1) Examine questions # 5b-5j, and assign scores for *each* question as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

#5b score ______
c score ______
d score ______
e score ______
f score ______
g score ______
h score ______
i score ______
j score ______

(2) Add the scores for questions # 5b-5j:

Sum of # 5b-5j: ______

(3) Assign component 5 score as follows:

Sum of # 5b-5j	Component 5 score
0	0
1-9	1
10-18	2
19-27	3

Component 5 score: ______

Component 6: Use of sleeping medication

Examine question # 7 and assign scores as follows:

Response	Component 6 score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Component 6 score: ______

Component 7: Daytime dysfunction

(1) Examine question # 8, and assign scores as follows:

Response	Score
Never	0
Once or twice	1
Once or twice each week	2
Three or more times each week	3

Question # 8 score: ______

(2) Examine question # 9, and assign scores as follows:

Response	Score
No problem at all	0
Only a very slight problem	1
Somewhat of a problem	2
A very big problem	3

Question # 9 score: ______

(3) Add the scores for question # 8 and # 9:

Sum of #8 and #9: ______

(4) Assign component 7 score as follows:

Sum of # 8 and #9	Component 7 score
0	0
1-2	1
3-4	2
5-6	3

Component 7 score: ______

Global PSQI Score

Add the seven component scores together:

Global PSQI Score: ______

(Buysse, et al., 1989)